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# Regenerative Piezo Amplifier

**“Miniature Piezomotors”**

(1/2000 - 6/2000)

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Principal Investigator

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SB992-0037



TIM/CHAP 6/00

## Phase I - Objectives

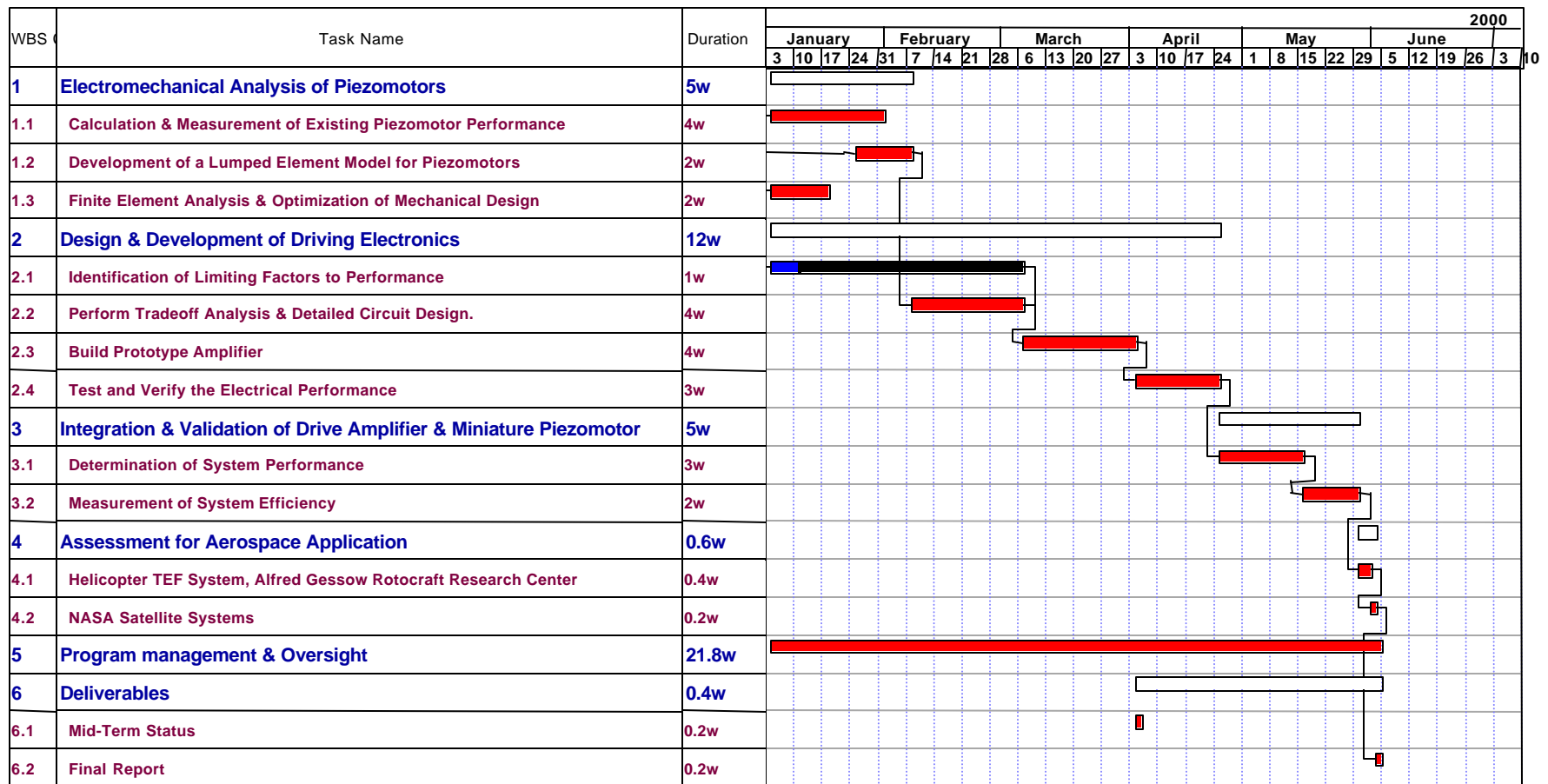
### Regenerative Piezo Amplifier

- Develop proof-of-concept, piezomotor drive amplifier electronics that operate efficiently at both electrical and mechanical resonance. [90% of effort]
- Identify the mechanical & materials engineering efforts that will be needed to miniaturize and optimize existing piezomotors in the future. [8% of effort]
- Demonstrate the amplifier for NASA Goddard and the Alfred Gessow Rotorcraft Research Center. [2% of effort]

## Proof-of-Concept Electronic Objectives

- **Drive capability:** up to 5  $\mu$ F and 300 Vrms
- **Drive efficiency:** > 80%
- **Drive frequency:** Continuously tunable up to 10 kHz
- **Output power:** 10 watts continuous
- **Packaging:** < 400 cc

# Piezo Amplifier Gantt Chart



## Subcontractors



### **PSU** - Pennsylvania State University's Center for Acoustics and Vibration

- Provide prototype rotary roller wedge piezoelectric motor for amplifier evaluation [100% complete]
- Support motor optimization and modeling efforts [100% complete]
- Test prototype motor using regenerative piezo amplifier [Waiting for amplifier]



## Subcontractors

### **UCLA** - University of California at Los Angeles' Active Materials Laboratory

- Evaluate piezoelectric stack actuators for inchworm motors [100% complete]
- Support motor optimization and modeling efforts [Optimization & modeling biased towards PSU motor only]

## Major Accomplishments

- **Energy Transfer & Timing Issues**

- \* Developed an idealized model
- \* Filed provisional patent application

- **Component Losses & Limitations**

- \* Low ESR capacitors, High voltage FET on-resistance & drive requirements, Low loss inductors/transformers

- **Prototype Amplifier Circuits**

- \* Built and under test & evaluation

- **Prototype Rotary Roller Wedge Motor**

- \* Delivered prototype motor to be used for amplifier loading

- **Piezoelectric Material Characterization**

- \* 3 commercially available stacks evaluated for electrical properties for use in existing inchworm motor

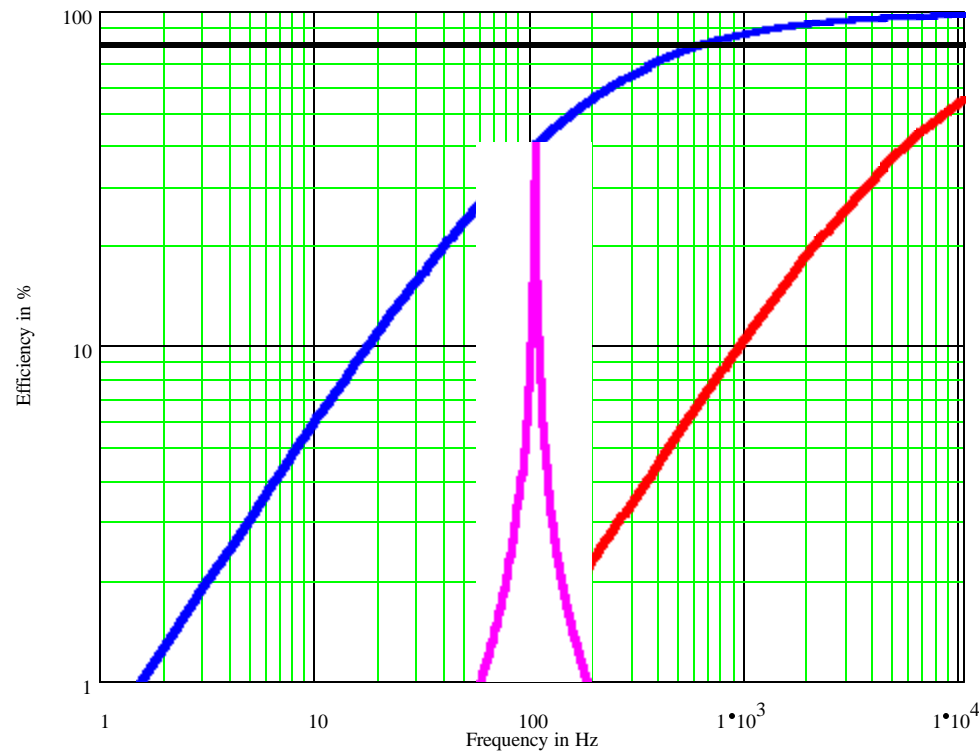
## Future Research & Applications

- **Electronic Design Optimization**
  - \* Improve analog computation methodologies (squares & square root calculations)
  - \* Mitigate alignment & calibration difficulties
- **Functional Enhancements**
  - \* Reduce sensitivity to actuator capacitance
  - \* Improve output waveshape fidelity
- **Customers & Applications**
  - \* Alfred Gessow Rotorcraft Research Center - Trailing flap
  - \* NASA Goddard - Satellite & telescope systems



# Amplifier Performance

## TYPICAL EFFICIENCIES FOR PIEZO-DRIVER SYSTEMS



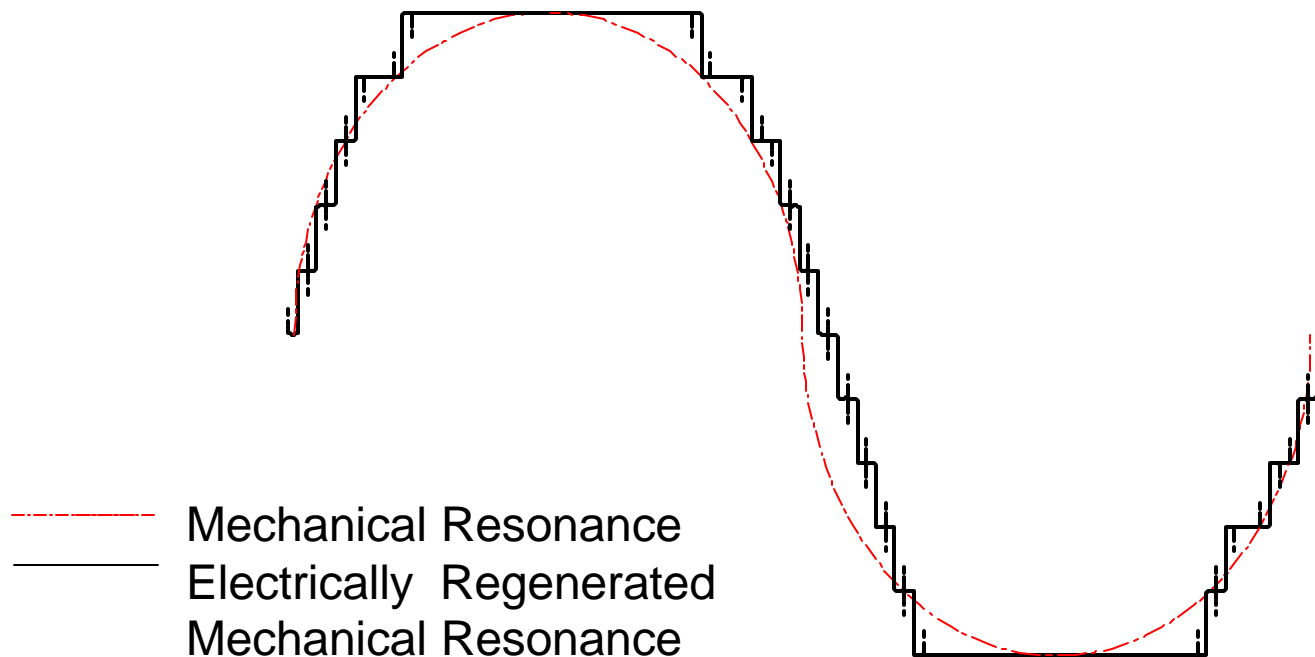
**Black** = Switching Regenerative Amplifier

**Blue** = Highest Efficiency of a Driven Tank Circuit

**Purple** = Fixed Value Tank Circuit

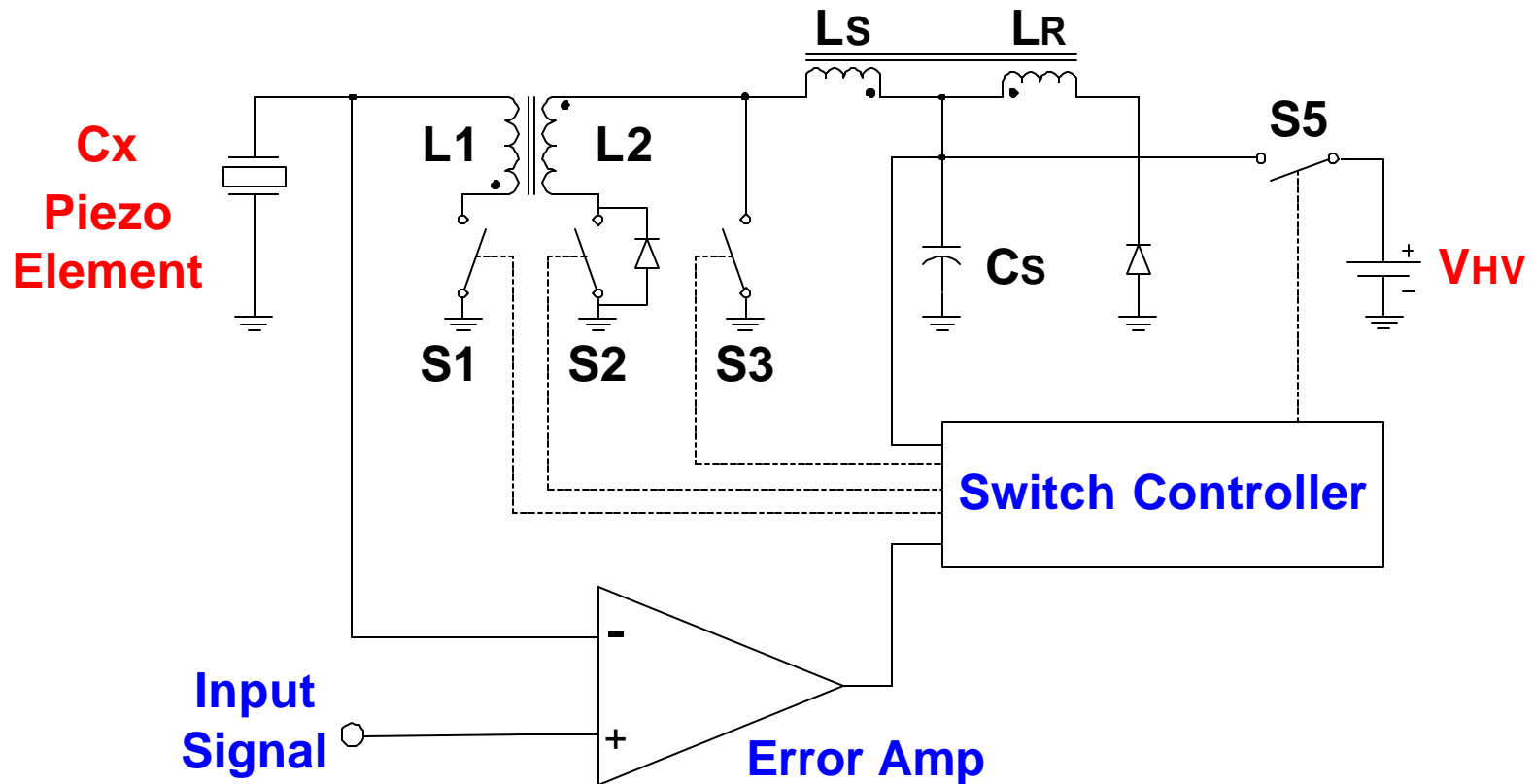
**Red** = Linear Amplifier

# Regenerative Piezo Drive Amplifier Resonant Wave Shapes

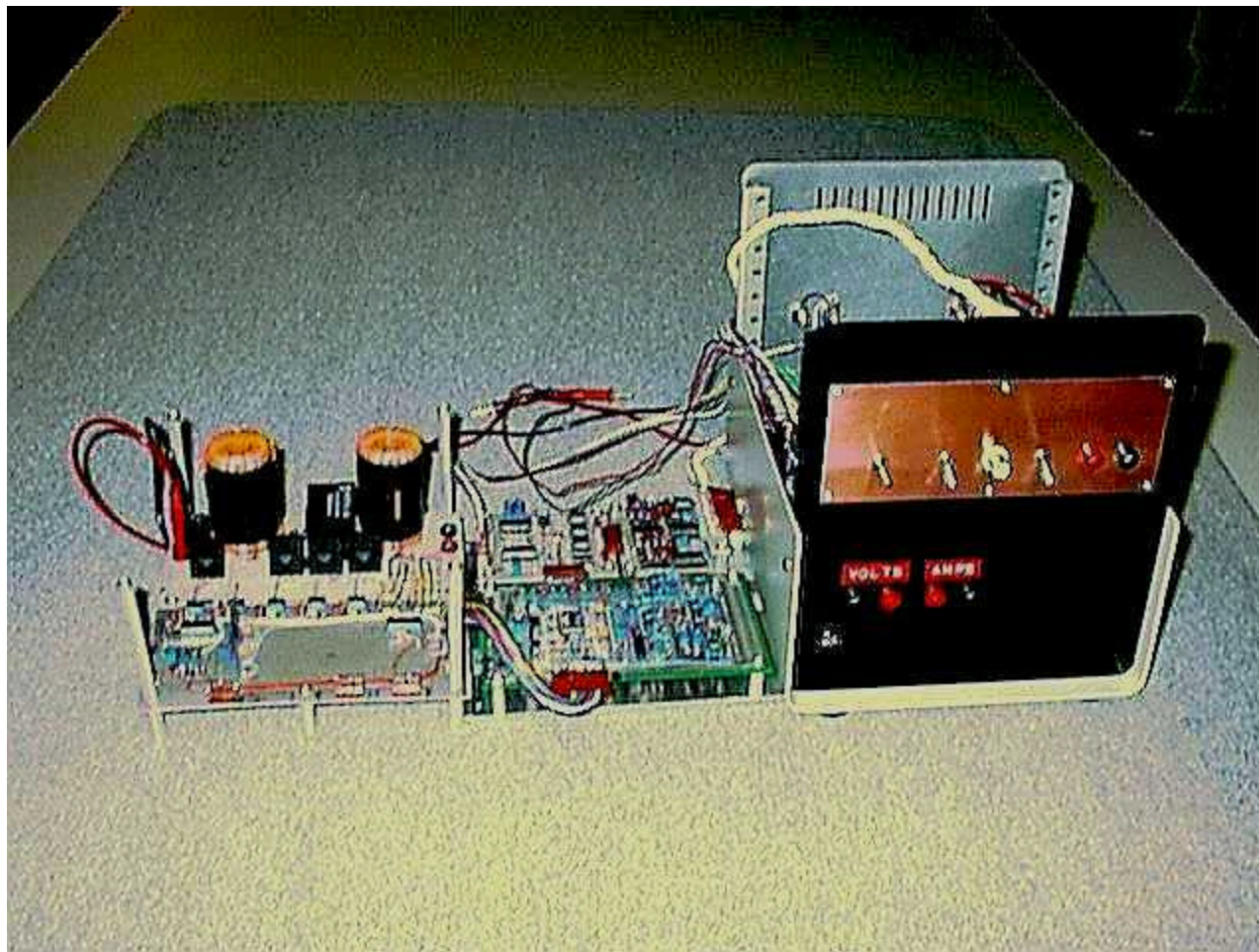


Mechanical Resonance  $\ll$  Electrical Resonance (50 KHz)

# Regenerative Piezo Drive Amplifier

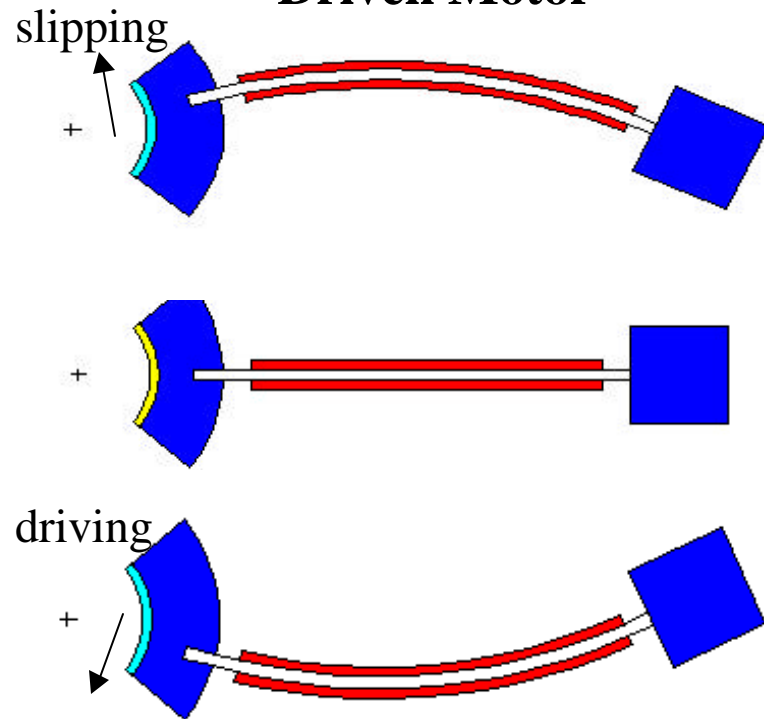


## Prototype Piezo Amplifier

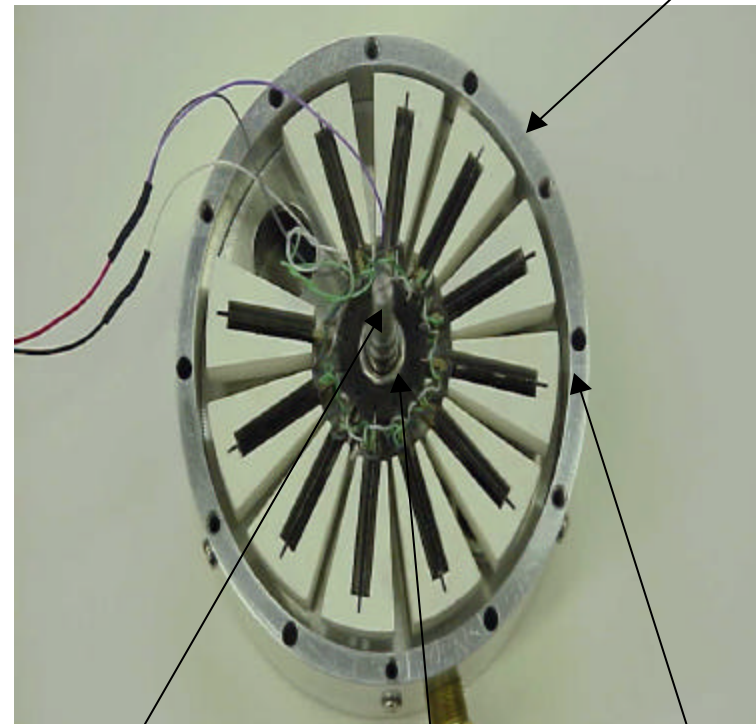


# Rotary Roller Wedge Motor

## Principle of Resonant Driven Motor



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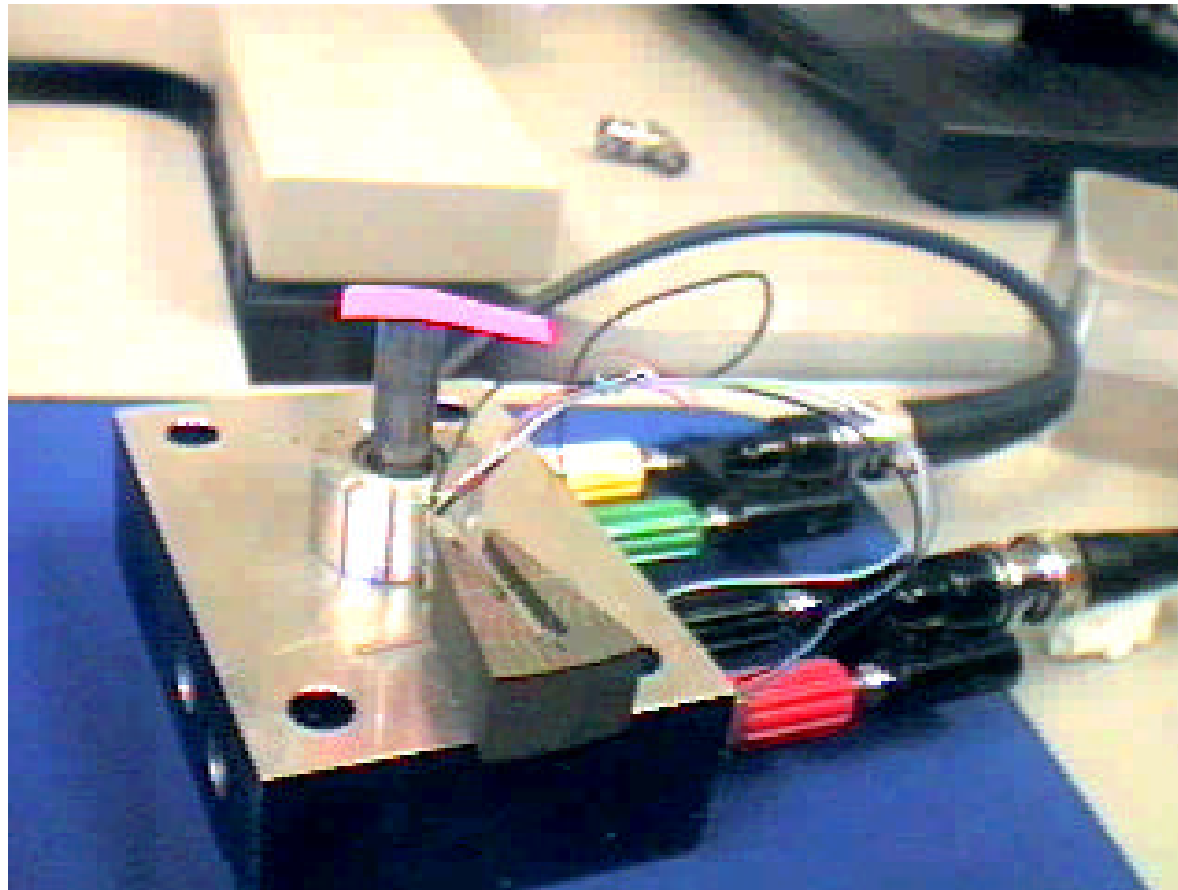
Mass

Driven shaft

Bimorph beam

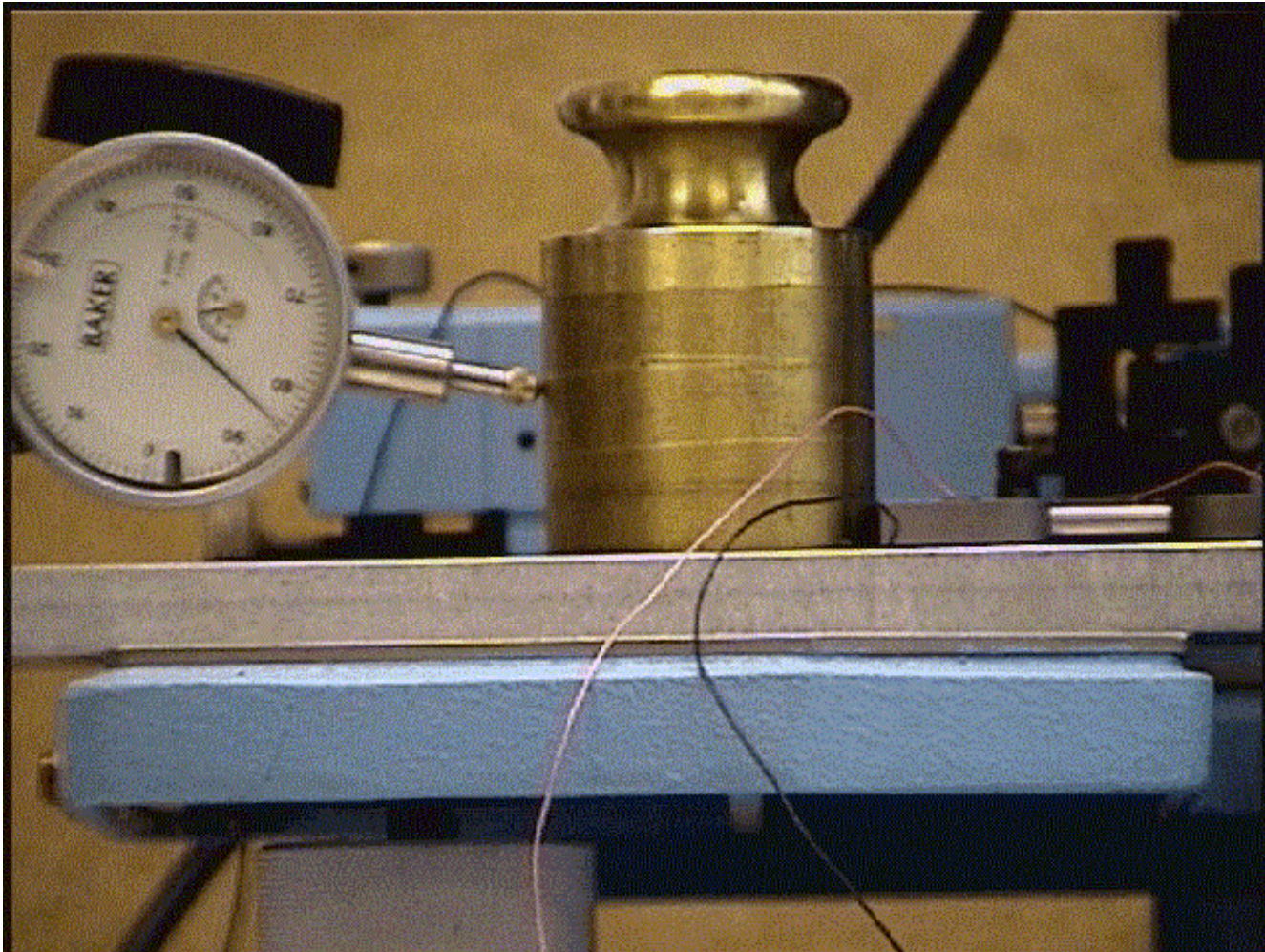
Roller clutch TIM/CHAP 6/00

## Single Bimorph Rotary Roller Wedge Motor

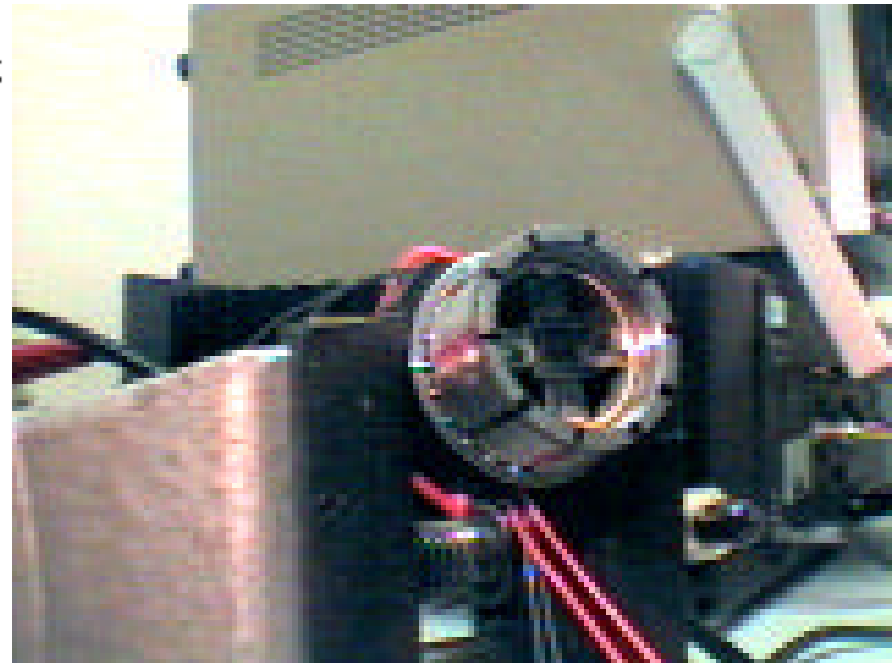
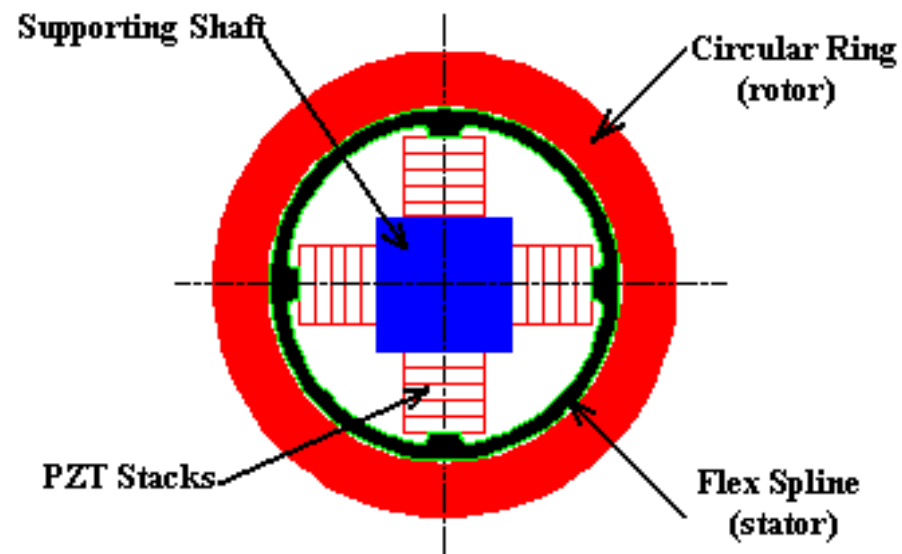




## Steel Inchworm Motor



## Harmonic Rotary Motor





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